Handbook of Reference Methods for Plant Analysis
Soil & Plant Analysis Council
CRC Press

The Handbook of Reference Methods for Plant Analysis is an outstanding resource of plant analysis procedures, outlined in easy-to-follow steps and laboratory-ready for implementation. Plant laboratory preparation methods such as dry ashing and acid and microwave digestion are discussed in detail. Extraction techniques for analysis of readily soluble elements (petiole analysis) and quick test kits for field testing are also presented. This handbook consolidates proven, time tested methods in one convenient source. Plant scientists in production agriculture, forestry, horticulture, environmental sciences, and other related disciplines will find the Handbook a standard laboratory reference.The Handbook was written for the Soil and Plant Analysis Council, Inc., of which the editor is a board member. The council aims to promote uniform soil test and plant analysis methods, use, interpretation, and terminology; and to stimulate research on the calibration and use of soil testing and plant analysis. This reference will help readers reach these important goals in their own research.

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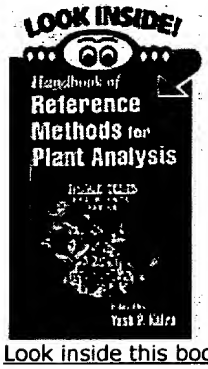

Handbook of Reference Methods for Plant Analysis

by Yash P. Kalra (Editor), Soil and Plant Analysis counc

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This resource consolidates standard procedures in plant analysis, including laboratory preparation methods such as dry ashing and acid and microwave digestion in detail, as well as extraction techniques for analysis of readily soluble elements (petiole analysis) and quick test kits for field testing. For plant scientists i n production agriculture, forestry, horticulture, environmental sciences, and related disciplines. *Book News, Inc.®, Portland, OR*

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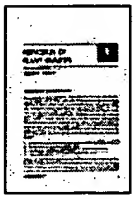
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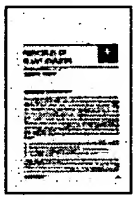

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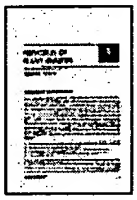
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HortFACT - Carnations - Plant Analysis - *Nutrient Testing of Leaves*

Maria van Dien, John Elgar - HortResearch, Palmerston North/Mt Albert

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Production of greenhouse carnations, both for export and local supply, is an important component of the floriculture industry in New Zealand, although export volumes have steadily declined over the last 6 years. Techniques and management vary, but in order to achieve optimum production, carnations need a nutrient supply adapted to suit their needs. Plant analysis can help in supplying valuable information as to their nutritional requirements.

Nutrients are supplied via the growing medium and by regular fertiliser application based on the plant requirements. Hence, a knowledge of the response of the crop to certain inputs is needed. Remember also, that when dealing with this type of crop, yield is not the prime factor, but needs to be considered along with the quality and economics of the crop.

Plant analysis can assess the concentration of various nutrients in the plant, and for the purpose of this Hortfact, we regard the status of the leaves as an indicator of the nutrient status of the whole plant.

If the concentration in the leaves is matched with recorded crop performance, valuable information is obtained which can be kept on file and used to evaluate nutrient supply to future crops. In doing this, it is necessary to consider other growth-controlling factors, such as light, temperature and general crop health.

In many laboratories around NZ, a plant analysis service has been provided for a number of years. The concentrations for the thirteen elements presented in this Hortfact are based on the distribution of values obtained and on the experience of horticultural advisory officers.

What and Where to Sample

Select sixty leaves representative of plants throughout the growing unit. Samples should be of the youngest mature leaves - 5th or 6th leaf from the top of the lateral growths. Ideally, samples should not be taken from a flowering lateral. If this is not possible, flower buds should be small.

Varieties should be kept separate as far as possible and diseased or damaged tissue avoided. Samples should also be clean.

Spray residues are impossible to remove and they will give high analytical results. It is therefore important that details of any recently-used sprays are included with the sample details.

Comments on Levels

Experience points to levels of N and K around 4.0% as most favourable. Rather than trying to fit all

crops into these guidelines, it is more valuable to analyse crops routinely and gauge performance at each set of figures. Do not forget to note other factors which may have influenced performance for each set of data. This will avoid comparisons between crops subject to different techniques, management and growing situations.

Table 1: Nutrient levels in the leaves of greenhouse carnations

Nutrient	Deficient	Low	Optimum	High	Excess
Nitrogen (% N)	<2.45	2.46-3.32	3.33-4.19	4.20-5.06	>5.07
Sulphur (% S)	<0.17	0.18-0.26	0.27-0.35	0.36-0.44	>0.45
Phosphorus (% P)	<0.11	0.12-0.25	026-0.40	0.41-0.52	>0.53
Magnesium (% Mg)	<0.18	0.19-0.28	0.29-0.39	0.40-0.49	>0 50
Calcium (% Ca)	<0.60	0.61-1.12	1.13-1.64	1.65-2.15	>2.16
Sodium (% Na)	–	–	0.10-0.50	–	–
Potassium (% K)	<1.89	1.90-2.78	2.79-4.00	4.01-4.50	>4.51
Manganese (Mn ppm)	<19	20-49	50-250	251-400	>401
Zinc (Zn ppm)	<15	15-19	20-60	61-100	>101
Copper (Cu ppm)	<2	3-5	6-10	11-30	>31
Boron (B ppm)	<19	20-29	30-100	101-200	>201
Molybdenum (Mo ppm)	–	<0.09	0.10-2.10	2.11	–
Iron (Fe ppm)	<39	40-50	51-120	121	–

Growers can find details about their local plant analysis laboratory in the Yellow Pages under soil testing and plant analysis.

References

Holley and Baker, 1963: *Carnation Production.* Wm C. Brown Co. Inc. Subuque, Iowa.

Langhans (ed.), 1961: *Carnations - a Manual of the Culture, Insects and Diseases, and Economics of Carnations.*

See also:
Carnations - Pre-planting for Commercial Production
Carnations - Harvesting and Post Harvest Practices for Commercial Production

Further Reading

- Read national and international floriculture magazines
- Browse the Internet for the latest information
- Contact a technical library such as a Crown Research Institute library

Acknowledgments

F.D. Dorofaeff from DSIR, Ruakura for writing the original Aglink, and Theo van Lier (van Lier Nurseries, Henderson, Auckland), and Tony Kay (Hills Laboratories, Hamilton), for editing of the revisions.

Prepared for HortNET - June 1998

Soil Testing and Plant Analysis, Third Edition

Soil Testing and Plant Analysis, Third Edition, summarizes the current knowledge and experiences on the use of soil testing and plant analysis as a diagnostic tool for assessing nutritional requirements of crops, efficient fertilizer use, saline-sodic conditions, and toxicity of metals. Discussions on analytical instrumentation used in soil testing, plant analysis, and data processing are included.

R.L. Westerman, ed.

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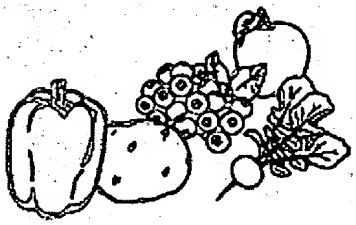
Nutrient Management for Commercial Fruit & Vegetable Crops in Minnesota

Carl J. Rosen and Roger Eliason
Department of Soil, Water, and Climate



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Introduction

There are 16 essential nutrients required for plant growth: carbon (C), hydrogen (H), oxygen (O), nitroge (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), iron (Fe), manganese (Mn), zinc (Zn), co (B), molybdenum (Mo), and chlorine (Cl). Of these 16, all except carbon, hydrogen, and oxygen are deri When the soil cannot supply the level of nutrient required for adequate growth, supplemental fertilizer a necessary.

Recommendations for fertilizing fruit and vegetable crops in Minnesota are based in part on soil test resu provides information on lime and fertilizer needs prior to planting and is particularly well calibrated for phosphorus, potassium, magnesium, calcium, sulfur, zinc, and boron. Soil testing prior to planting takes of making fertilizer recommendations and leads to more efficient nutrient management. Fertilizer recom bulletin are intended for field-grown fruit and vegetable crops. For container-grown crops such as transp grown in the greenhouse in pots, different soil tests should be used. Contact the University of Minnesota Laboratory (612-625-3101) for the appropriate form to fill out for container-grown crops. For fertilizer r established perennial crops and for fine-tuning fertilizer needs of annual crops, a combination of soil tes

Grapes1.6-2.80.20-0.461.5-2.01.2-2.50.30-0.40-40-18025-505-1025-10025-1000.2-0.4
Lettuce2.5-4.00.40-0.606.0-8.01.4-2.00.50-0.70-50-50030-1007-1026-10030-90>0.1
Onions5.0-6.00.35-0.504.0-5.51.5-3.50.30-0.500.50-1.060-30030-455-1020-5550-65-
Peas4.0-6.00.30-0.802.0-3.51.2-2.00.30-0.700.20-0.4050-30025-605-1025-10030-400>0.6
Peppers3.5-4.50.30-0.704.0-5.40.4-0.60.30-1.50-60-30030-10010-2030-10026-300-
Potatoes (leaf)3.5-4.50.25-0.504.0-6.00.5-0.90.25-0.500.19-0.3530-15020-405-2020-4020-450-
Potatoes-0.22-0.408.0-10.00.6-1.00.30-0.550.20-0.3550-20020-404-2020-4030-300-
(petiole)
Pumpkin/4.0-6.00.35-1.00 4.0-6.01.0-2.50.30-1.00-60-30025-756-25 20-20050-250-
Squash
Radishes3.0-6.00.30-0.704.0-7.53.0-4.50.50-1.200.20-0.4050-20030-506-1220-5025-130-
Raspberries2.2-3.50.20-0.501.1-3.00.6-2.50.25-0.800.20-0.3050-20025-3004-2015-6025-300-
Spinach4.2-5.20.30-0.605.0-8.00.6-1.20.60-1.00- 60-20025-605-2525-10030-250>0.5
Strawberries2.1-2.90.20-0.351.1-2.50.6-1.80.25-0.700.20-0.3090-15025-606-2020-5030-100-
Sweet corn2.8-3.50.25-0.401.8-3.00.6-1.10.20-0.500.20-0.7550-3008-255-2520-10030-3000.9-1.0
Tomato4.0-6.00.25-0.802.9-5.01.0-3.00.40-0.600.40-1.240-20025-605-2020-5040-250-
Watermelon2.0-3.00.20-0.302.5-3.52.5-3.50.60-0.80-100-30030-804-820-6060-240-

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[1]*Portions of this table were adapted from Plant Analysis Handbook by J.B.Jones, Jr., B. Wolf, and H.A. Publishing, Inc., 1991.*

Tissue Nitrate Analysis for Vegetable Crops

Tissue nitrate analysis has proved to be a valuable tool to guide in season applications of nitrogen. The t sampled for analysis is the leaf petiole, although for some crops the leaf midrib is collected. The petiole of the leaf. Petiole analysis is especially recommended for scheduling nitrogen applications for overhead and has been used extensively for potato production. Traditional petiole analysis is based on collecting p stages of growth, sending the petioles to a laboratory, and then receiving results of the nitrate analysis w week. Results are presented on a dry weight basis. For most crops, the plant part to sample is the most re All leaflets or leaf blade portions should be removed immediately and the petiole saved for analysis (see some crops such as cabbage, broccoli, cauliflower, and lettuce, the leaf midrib should be saved for analy Time of day can affect tissue nitrate concentrations. To reduce variability, it is recommended that tissue noon. Tissue handling is similar to that described above for plant analysis.

Advances have also been made in quantitative determination of nitrate in petiole sap. Portable nitrate ele Cardy meter and color test strips have been shown to be useful for determining nitrogen needs. The adva is that results can be obtained more quickly than with conventional dry weight analysis. The same tissue analysis as for conventional petiole analysis. The difference is that instead of drying the tissue in a labor are crushed to express the sap and then the sap is immediately analyzed for nitrate.

Ideally, petioles should be processed immediately; however, if this is not possible, whole petioles can be bag on ice in a cooler or in a refrigerator for up to 8 hours or at room temperature for up to 2 hours. Be s blade portions have been removed before storing.

Sap can be expressed with a garlic press or hydraulic sap press. Petioles can also be placed in a plastic b: with a rolling pin to express the sap. Follow sap analysis instructions of the manufacturer. For the Cardy generally does not need to be diluted. For other portable electrodes or the color test strips, the sap needs obtain an accurate reading.

Most interpretations are on a nitrate-N basis. In some cases, results are expressed on a nitrate basis inste: basis. To convert from ppm nitrate to ppm nitrate-N, multiply ppm nitrate by 0.225. Nitrate concentratio as the crop matures and the season progresses. Therefore, interpretation is based on stage of growth. Niti concentrations on a dry weight or sap basis for selected crops are presented in **Table 48**. If nitrate-N con below the sufficiency range, then fertigation with urea-ammonium nitrate is recommended. An applicati N/A can be made with overhead irrigation systems. Smaller (5 to 10 lb N/A) more frequent applications drip irrigation.

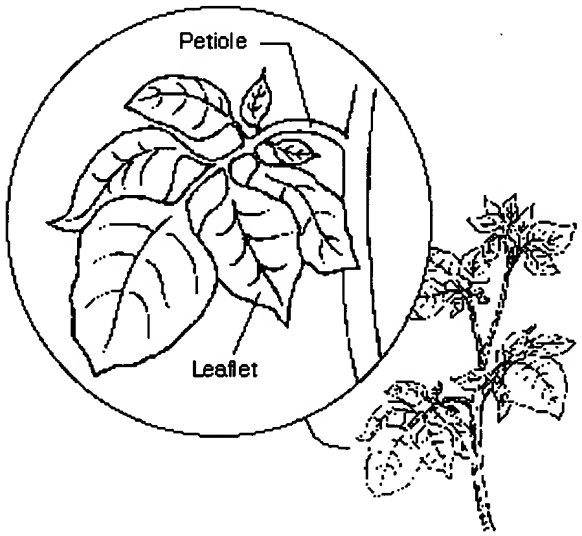

Figure 3. *Potato leaf petiole consisting of leaflets and petiole.*

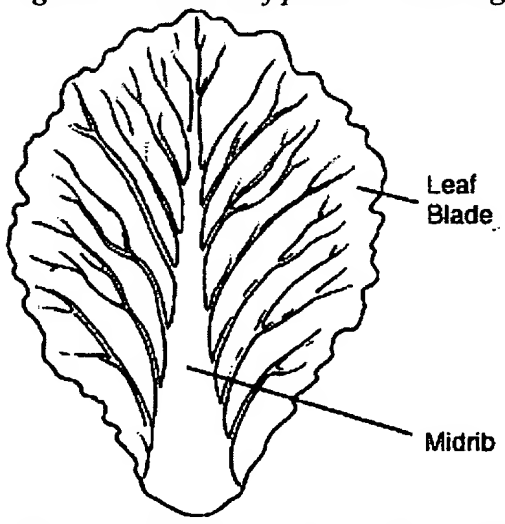

Figure 4. *Cabbage leaf consisting of midrib and blade.*

Table 48. *Sufficiency nitrate-N concentration ranges for petioles/midribs of selected vegetable crops on sap basis. Petioles/midribs should be collected from the most recently matured leaf.*[1]

Crop	Tissue Sampled	Growth Stage	Nitrate-N	
			dry weight	sap
			%	ppm
Broccoli	Midrib	Buttoning	0.9 - 1.2	800 - 1100
Cabbage	Midrib	Heading	0.7 - 0.9	NA
Carrots	Petiole	Midgrowth	0.75 - 1.0	550 - 750
		1/4inch diameter		
		shoulder		
Cauliflower	Midrib	Buttoning	0.7 - 0.9	NA
Celery	Petiole	Midgrowth	0.7 - 0.9	500 - 700
Cucumbers	Petiole	First blossom	0.75 - 0.9	800 - 1000
		Early fruit set	0.5 - 0.75	600 - 800
		First harvest	0.4 - 0.5	400 - 600
Eggplant	Petiole	Initial fruit	NA	1200 - 1600
		First harvest	NA	1000 - 1200
Lettuce	Midrib	Heading	0.6 - 0.8	NA
Muskmelon	Petiole	First blossom	1.2 - 1.4	1000 - 1200
		Initial fruit	0.8 - 1.0	800 - 1000
		First mature fruit	0.3 - 0.5	700 - 800
Peppers	Petiole	First flower	1.0 - 1.2	1400 - 1600
		Early fruit set	0.5 - 0.7	1200 - 1400
		Fruit 3/4 size	0.3 - 0.5	800 - 1000
Potatoes	Petiole	Vegetative	1.7 - 2.2	1200 - 1600
		Tuber bulking	1.1 - 1.5	800 - 1100
		Maturation	0.6 - 0.9	400 - 700
Tomatoes	Petiole	Early bloom	1.4 - 1.6	1000 - 1200
		Fruit 1 inch diameter	1.2 - 1.4	400 - 600
		Full ripe fruit	0.6 - 0.8	300 - 400
Watermelon	Petiole	Early fruit set	0.75 - 0.9	1000 - 1200

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NebGuide

Published by Cooperative Extension, Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln

Using a Chlorophyll Meter to Improve N Management

This NebGuide describes how to use a chlorophyll meter as a tool to improve nitrogen management by detecting nitrogen deficiency and determining the need for additional N fertilizer.

Todd A. Peterson, Extension Cropping Systems Specialist
Tracy M. Blackmer, Graduate Research Assistant
Dennis D. Francis, Soil Scientist, USDA-ARS
James S. Schepers, Soil Scientist, USDA-ARS

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- Field Use of the Chlorophyll Meter

Fertilizer nitrogen (N) is increasingly recognized as the source of nitrate contamination in much of Nebraska's groundwater. Improving the efficiency of fertilizer N use reduces the amount of N that can potentially contaminate water resources. Effective management of fertilizer N is a major challenge for grain crop producers. Many factors that affect its efficiency are beyond a producer's control. Weather, equipment limitations and breakdowns, and availability of labor and fertilizer during critical periods can lead to inadequate N supply to the crop. Fertilizer N is relatively inexpensive, and deficiencies can result in substantial yield reductions. Producers are inclined to manage fertilizer N to minimize the risk of deficiency, which can lead to excessive fertilizer applications. Although they understand fertilizer applied at excessive rates costs money and may lead to contamination of the environment, producers also want assurance that applying less fertilizer N will not reduce crop yields.

Researchers have been looking for ways to increase fertilizer N use efficiency. The use of a soil test to adjust fertilizer N rates for residual nitrate works well under Nebraska conditions and producer acceptance of the practice is increasing. However, the potential exists to "fine-tune" N management decisions during the growing season to react to changing weather and crop conditions.

Figure 1. A chlorophyll meter in use.

The concept of using tissue testing to provide an assessment of crop N status is not new. Recent research indicates a close link between leaf chlorophyll content and leaf N content, which makes sense because the majority of leaf N is contained in chlorophyll molecules. The Minolta[1] chlorophyll meter (model SPAD 502) enables users to quickly and easily measure leaf greenness which is affected by leaf chlorophyll content. Chlorophyll content or leaf greenness is affected by a number of factors, one being N status of the plant. Since the chlorophyll meter has the potential to detect N deficiencies, it also shows promise as a tool for improving N management.

The chlorophyll meter (see *Figures 1* and *2*) has several advantages over other tissue testing methods. A reading that indicates adequate nitrogen (or critical value) is not affected by luxury consumption; a plant will only produce as much chlorophyll as it needs regardless of how much N is in the plant. It is not necessary to send samples to a laboratory for analysis, saving time and money. Producers can sample as often as they choose, and can easily repeat the procedure if they question the results. Using a chlorophyll meter to monitor leaf greenness throughout the growing season can signal the approach of a potential N deficiency early enough to correct it without reducing yields.

Figure 2. Close-up of chlorophyll meter.

Monitoring crop N status during the growing season accomplishes little unless it is possible to correct an N deficiency before it reduces yields. Using a chlorophyll meter as an N management tool is especially appropriate where additional N can be applied through the irrigation system (fertigation). Fertigation is generally limited to moving sprinkler systems due to the uniformity of application possible with center pivots or lateral move systems, although much progress is reported in the development of surge-flow fertigation systems. Fertigation applications in Nebraska must conform to state chemigation regulations which require certification of the operator and inspection of the required safety equipment (see your local Natural Resources District).

In non-irrigationd cropping systems additional N fertilizer can be injected with a sidedress application if crops are not too tall, or broadcast or banded between rows using high-clearance equipment. One benefit of fertigation is that the applied N is rapidly taken up by the crop to correct the N deficiency. In a non-irrigationd system, N application to dry topsoil may not be utilized until the next rain occurs, which may be too late for the plants to fully recover and produce optimal grain yields. Although the technique is quite new, we feel chlorophyll meters can be utilized on a large number of acres in Nebraska, and promises to improve fertilizer N efficiency and decrease risks associated with reduced fertilizer applications.

Many factors affect chlorophyll meter readings. Variety or hybrid differences can greatly affect the meter reading as some corn and sorghum hybrids are darker green than others. Stage of growth can affect leaf greenness as can recent environmental conditions such as temperature, moisture stress and sunlight. Plant diseases, nutrient deficiencies and nearly any other kind of plant stress can affect the ability of the plant to produce chlorophyll, thus affecting leaf greenness. Because the chlorophyll meter is affected by so many things, we are not able to say that a given meter reading indicates sufficient N. Meter readings mean very little by themselves and must be calibrated for each field, soil, hybrid and environment in order to make use of the readings. The best way to calibrate the meter is to maintain several adequately

fertilized reference strips in each field.

Field Use of the Chlorophyll Meter

1. **Establishing Reference Strips**. For reasons outlined above, it is crucial that the chlorophyll meter be calibrated for each field, previous crop, hybrid, fertilizer and/or manure application and differing soil types. Several adequately fertilized reference strips, identical to the rest of the field except that they receive sufficient levels of nitrogen fertilizer, should be established in each field. The amount of N applied to these strips should be adequate to insure that plants in the reference strip do not exhibit an N deficiency.

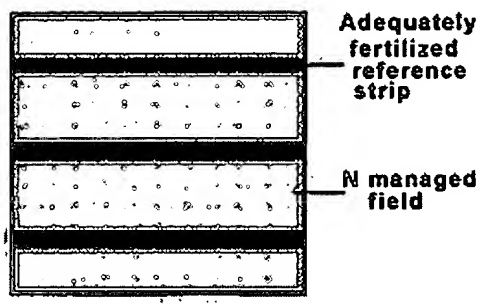

Figure 3. Field planted with reference strips.

We suggest that **the entire field be fertilized with one-half to two-thirds of the total amount of fertilizer N recommended** by standard soil test procedures. The reference strips should then be established by applying additional N fertilizer so the total amount applied to the strips is equal to or slightly higher than the N rate suggested by the University of Nebraska (see NebGuide G74-714, *Fertilizer Recommendations for Corn*). A large excess of N applied to the reference strips is not recommended and may reduce yields. Three to five reference strips should be established in each field to accurately represent conditions in that field (see *Figure 3*). By comparing the average chlorophyll meter readings from the reference strips to those from the rest of the field, N sufficiency and the need for additional N supplied through fertigation can be determined.

2. **How to sample**. Weekly chlorophyll meter readings from the reference strip and the bulk field should be compared at a minimum of three locations in each field. At each location, the average reading of 30 plants from the reference area and the adjacent bulk field should be compared. The Minolta SPAD 502 collects and stores up to 30 individual readings and calculates the average automatically. Care must be taken during collection of these readings to insure their accuracy. Individual readings will vary up to 15 percent from plant to plant, but the goal is to collect 30 readings so that the average accurately represents leaf greenness for that crop. Avoid taking readings from plants that do not represent typical plant spacings (e.g., wide guess rows, doubles or planter skips). It may be helpful to systematically sample each row across the planter width to avoid problems caused by differences among rows such as plant population, compaction or variations in starter or other fertilizer application.

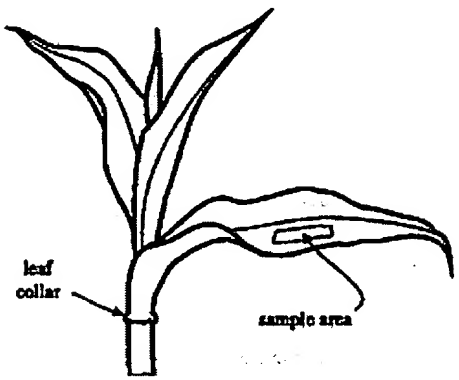

Figure 4. Sample area for taking chlorophyll readings.

The same leaf should be sampled from each plant. Avoid sampling very old or very young leaves. For plants between the six leaf stage (about 1 foot tall) and tassel, we recommend sampling the newest fully expanded leaf that has a leaf collar exposed (see *Figure 4*). After the tassel stage, sampling the ear leaf (the leaf attached to the primary ear shank) should give an accurate comparison. Readings taken from plants less than 1 foot tall are usually quite variable and probably not worth collecting. After selecting the leaf to be sampled, it is important to take the reading on about the same location on each leaf. We have found it works well to collect the reading from a point one-half the distance from the leaf tip to the collar, and halfway between the leaf margin or edge and the leaf midrib (*Figure 4*). Chlorophyll meter readings may vary with time of day, but as long as readings are collected from the reference strip and the bulk field at about the same time, the comparison is valid. It is best to avoid collecting readings whenever there is moisture on the leaves (i.e., after a rain or sprinkler irrigation or in the early morning) as this can distort the readings. Extreme temperature changes can cause meter readings to fluctuate, so the meter should not be left in the sun on a vehicle dashboard or taken from an air conditioned vehicle directly to the field on a hot day.

3. **Interpretation of chlorophyll meter readings**. After recording average meter readings from the bulk field and reference area at several locations in each field, an N sufficiency index can be calculated as follows:

$$\text{Sufficiency Index} = \frac{\text{Average Bulk Reading}}{\text{Average Reference Strip Reading}} \times 100\%$$

For example 1, we sampled four places in the field and obtained the following N sufficiency index values: 101, 98, 97, and 96 percent (see worksheet). Our experience shows that a sufficiency index lower than 95 percent indicates an N deficiency that should be corrected or it may lead to a yield reduction. In example 2 (see worksheet) the readings average less than 95 percent, indicating the need for additional N. At least 20 lbs N/acre should be applied through the irrigation system to correct the N deficiency, particularly since we know the crop is rapidly taking up N during this period. This field should be checked again with the meter 4-6 days after the N application to make sure the deficiency has been corrected or that recovery is under way.

Since the readings vary depending on weather and growing conditions, readings collected from a single sampling date are not as useful as comparing trends in the sufficiency index through the growing season. Readings should be collected weekly from the six leaf stage until about 20 days after silking. Fertigations applied later than this do not increase yield.

4. **The chlorophyll meter as an N management tool**. It is important to realize that the chlorophyll meter enhances a producer's ability to make N management decisions but does not replace other aspects of good N management. Environmentally and economically sound N management must begin with a representative soil sample and a realistic value for expected yield. We suggest that at least one-half to two-thirds of the total fertilizer N be applied to the entire field prior to the six leaf stage in order to insure the chlorophyll meter technique is effective. If a corn plant experiences severe N stress in the early growth stages, the size of the ear and number of kernels can be limited

so additional N fertilizer applied later will not allow full recovery of grain yield.

Using the chlorophyll meter to schedule fertigations allows adjustments throughout the season based on the amount of N supplied by mineralization of organic matter and manure, by contaminated irrigation water, or when plant roots come in contact with additional N.

When the need for additional N is indicated by the chlorophyll meter (e.g., N sufficiency index is at or below 95 percent, or a trend indicates it soon will be), an additional 20 to 40 pounds N per acre should be applied through fertigation. The decision on how and when to fertigate is affected by many factors including stage of growth, developing trends in chlorophyll meter readings, equipment limitations and anticipated crop N needs for the rest of the growing season. Most N fertilizer should be applied before the tassel stage. N applied more than 20 days after silking probably will not affect grain yields. Generally chlorophyll meter readings will respond to show crop recovery within two to three days after fertigation depending on environmental conditions.

The chlorophyll meter technique allows "fine-tuning" N management to field conditions and reduces the risk of yield-limiting N deficiencies. Producers should recognize this as another tool that may complement, but does not replace, other aspects of sound N management. One soil scientist said it succinctly, "Use the chlorophyll meter to schedule your last 50 lbs N/acre, not your first." Potential uses of these techniques in the future may include remote sensing by satellite or airplane to schedule the need for additional fertilizer N.

[1]Mention of a brand name does not imply endorsement by the University of Nebraska or the USDA Agricultural Research Service.

Worksheet Example 1.

Field: North 80		Date: June 28	
	Average Bulk Field Reading	Average Reference Strip Reading	N Sufficiency Index
Location 1	54.5	54.1	100.7%
Location 2	56.8	58.0	97.9%
Location 3	49.6	51.3	96.7%
Location 4	57.2	59.5	96.1%
		Average	97.9%
Action: none required			

Worksheet Example 2.

Field: South 40		Date: July 10	
	Average Bulk Field Reading	Average Reference Strip Reading	N Sufficiency Index
Location 1	50.2	52.4	95.8%
Location 2	48.2	51.6	93.4%
Location 3	51.3	54.4	94.3%
Location 4	54.0	58.1	92.9%
		Average	94.1%
Action: Fertigate			

Your Data

Field: _____		Date: _____	
	Average Bulk Field Reading	Average Reference Strip Reading	N Sufficiency Index
Location 1	_____	_____	_____
Location 2	_____	_____	_____
Location 3	_____	_____	_____
Location 4	_____	_____	_____
Location 5	_____	_____	_____
		Average	_____
Action: _____			Average: _____

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Ascorbic Acid and Vitamin A Content of Edible Wild Plants of Ohio and Kentucky

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Fresh samples of 16 wild edible plants were assayed for Ascorbic Acid and 10 plants were assayed for Vitamin A. Many of the plants were found to be rich sources of these vitamins when compared with some common garden fruits and vegetables.

INTRODUCTION

There is a renewed awareness today of the value of natural resources, and this realization ha sled to experimentation with an increased utilization of wild plants as food sources (3,4,6,7,8,9,13,17). In some areas of the United States the utilization of such foods is not new. The practice has been handed down through generations and is undoubtedly a carry-over from the times when some pioneers and American Indians subsisted wholely on native foods. Wild spring greens are often available several weeks before garden varieties and are used extensively by individuals familiar with them. Dandelion and wild Asparagus are common foods to some people. Tender Poke greens and Lambs-quarters are consumed in such quantities by some families that they are a standard part of the diet - often being preferred to garden greens. Non-cultivated fruits such as blackberries, blueberries and plums are collected in sufficient quantities to be used in preserving for a winter home supply or for sale on the market. We utilize edible wild plants on a regular basis, and in fact, are delighted when various species are in their prime.

Books on wild edible plants often contain such statements as, "Rose hips are rich in Vitamin C" or " Sassafras leaves are anti-scorbutic" but only a few references have included quantitative analysis of tested wild foods of particular vitamins, minerals and/or other ingredients (1,6,12). Some references are difficult to locate (11) and some do not include details of the assay procedures (3,6,17). At best there is a paucity of information regarding the nutritive values of wild plants, and it is for the purpose of extending the knowledge of vitamin content of commonly consumed wild plants that the study was undertaken.

PLANTS USED

A selection of wild foods utilized in southern Ohio and northern Kentucky were analyzed for their content of the vitamin A precursor, beta carotene, and ascorbic acid. The plants were chosen because of their availability at the time of the experiment and because their vitamin content was expected to be high. No effect was made to exhaust all the usable species of the area and no effort was made to follow the level of vitamins in the plants through their growing season, although there are values reported for several plants collected at different stages of development.

Table I lists the plants assayed with the following information - common names used in the southern Ohio and northern Kentucky area, the part of the plants used, and the time of year when the plants are usually collected for food. Specimens of all plants are on file in the herbarium of the University of Cincinnati.

Table I Vitamin A and Ascorbic Acid values for some edible wild plants

Plant Name	Part Used	Season Collected	Pro Vitamin A (Units/100 g)
Alliaria officinalis L. *Cruciferae* *(Garlic Mustard)*	(1) Leaves and tops just prior to flowing (2) Basal leaves	(1) Spring (2) All year	8,600 (3) 12,000 19,000
Allium vineale L. *Liliaceae* *(Onion Grass)*	Leaves	All year (best in early spring)	n/a
Allium tricoccum Ait. *Liliaceae* *(Ramps or Wild Leeks)*	Leaves	Spring	n/a
Barbarea vulgaris R. Br. & Barbarea verna Asch. *Cruciferae* *(Winter Cress)*	Basal leaves	Late winter and early spring	n/a
Capsella bursa-pastorisMedic. *Cruciferae* *(Shepard's Purse)*	Basal leaves of first year plants	Late winter and early spring	5,000
Cercis canadensis L. *Leguminosae* *(Redbud, Judas Tree)*	Flowers	Early spring	n/a
Chenopodium album L. *Chenopodiaceae* *(Goosefoot, Lambsquarters)*	(1) Whole young plant (2) Tops of older plants	(1) Early spring (2) Later in year	14,000 16,000
Chyrsanthemum Leucanthemum L.	Basal	Later winter and early spring	7,000 12,000

Compositae *(Ox-eye Daisy)*			
Duchesnea indica *Focke. Rosaceae* *(Indian Strawberry)*	Leaves	All year (best in spring)	n/a
Glechoma hederacea L. *Labiatae* *(Ground Ivy)*	Leaves	All year	14,000
Lactuca scariola L. *Compositae* *(Wild Prickly Lettuce)*	Basal leaves	Early spring	9,700
Oxalis stricta L. *Oxalidaceae* *(Sour Grass)*	Leaves	All year	n/a
Physalis pubescens L. *Solanaceae* *(Ground Cherry)*	Ripe fruit only	Late fall and early winter	3,200 2,200
Plantago major L. Plantaginaceae (Plantain)	Leaves	Early spring	10,000 11,000
Portulaca oleracea L. *Portulacaceae* *(Purslane)*	Overground plant prior to flowering	Spring and winter	6,100 8,300
Stellaria media Cyrill *Caryophylaceae* *(Chickweed)*	Overground plant	All year (best in spring)	n/a
Viola papilionacea Puesh. *Violaceae*	Basal leaves	All year (best in spring)	15,000 20,000

(Common Blue Violets)			

(1) Plants collected the day before the assay.

(2) Values from old plants that had gone to seed.

(3) Value from plants collected in late winter.

METHODS

Collection of plant material Parts of the plant suitable and most desirable for human consumption were used in all cases. In general this consisted of young, tender parts; discolored and insect-damaged portions were discarded. Most of the samples were collected just prior to or during the flowering period, because it was expected that the vitamin content would be at its highest level at that time (1, 14). Some plants were not at their prime when the field trips were made or when the assays were being done, and for that reason portions were collected from some older plants, ones that had gone to seed, with this difference noted in Table I. All plants were collected within a 50-mile radius of Cincinnati and taken directly to the laboratory. The analysis was done immediately upon arrival and, with one exception as noted on Table I, all values reported are for fresh samples.

Chemical assays, Vitamin C. The method used for the ascorbic acid determination was that of the Association of Vitamin Chemists (2, 15), a 2,6-dichloroendophenol method that measures only reduced ascorbic acid. The dehydroascorbic acid method of Roe and Oesterling (2) was not used because the plants usually were analyzed within ten or fifteen minutes of collection and, consequently, the amount of dehydroascorbic acid would have been small in comparison with what it would have been in older or frozen samples. The dehydroascorbic acid method is open to question because the biological activity of the vitamin is impaired once the ascorbic acid is oxidized to the dehydro form in the plant leaf (16).

Vitamin A. The method used for the assay of a vitamin A precursor follows that of Strohocker and Henning (15) and the Association of Vitamin Chemists (2). Extracted carotene was measured against a highly purified sample of A100% type VI beta-carotene obtained from carrots@ using a Spectronic 20 spectrophotometer at wave length 435 nm. Carotenes from several samples were collected and measured against the purified beta-carotene standard using a Coleman U.V. spectrophotometer, Model 124. The scans of the extracted carotenes were qualitatively indistinguishable from that of the standard, indicating that beta-carotene was the principal extracted carotene. Units of vitamin A were calculated by multiplying the mcg/100 g of beta-carotene by 1.6 (2).

RESULTS

Results of the assays are seen in Table I. For those plants of which a single collection was made, a single value is given. This value represents the average of three assayed portions. For those plants having unusually high vitamin contents, additional collections and assays were performed. Only the high and low values obtained from the various different collections are given.

CONCLUSIONS AND DISCUSSIONS

The carotene values of ten edible wild plants were determined. On a weight basis, six had higher values for carotene than spinach (16), which is reported to have the highest vitamin A level of the widely marketed garden vegetables (see Table II). For the following plants - *Alliaria officinalis, Capsella bursa-pastoris, Chenopodium album, Chrysanthemum leucanthemum, Glechoma hedaracea, Lactuca*

scariola, Plantago major, Portulaca oleracea, and Viola papilionacea - each could provide for at least a daily dietary allowance (5,000 units) of vitamin A (5) in a 100 g sample. One collection of *Viola papilionacea* contained a daily dietary allowance in a 25 g quantity.

Table II Vitamin A and Ascorbic Acid Values for some common garden fruit and vegetables (15)

Domestic Vegetables	Pro Vitamin A, Units/100 g	Ascorbic acid mg/100 g
Celery	240	9
Iceberg lettuce	330	6
Leaf lettuce	1,900	18
Green onions	2,000	32
Green peppers	240	128
Spinach	8,100	51
Oranges	200	50
Tomatoes	900	23

The ascorbic acid values of 16 edible wild plants were determined. When compared with oranges, on a weight basis, ten of the wild plants had higher values of vitamin C: *Alliaria officinalis, Allium vineale, Allium tricoccum, Barbarea vulgaris, Capsella bursa-pastoris, Cercis canadensis, Chenopodium album, Duchesnea indica, Oxalis stricta, and Viola papilionacea.* Each would provide more than a daily dietary amount of vitamin C in a 100 g sample of the food for an average man or for a woman during pregnancy and lactation (60 mg) (5).

The edible wild plants tested have relatively high carotene or ascorbic acid values or both and could be useful components of the diet, particularly for rural families. Most of the plants are found in abundance in Ohio and Kentucky, and collection of a mess for a family sufficient to provide a daily dietary allowance of the vitamins would be a relatively easy task. Many of the plants may be collected in late winter or early spring when commercial sources of fresh foods may be scarce or expensive and a supply of vitamins from purchased foods may be relatively low. Preferably the plants should be consumed prior to wilting or aging so that the palatability and vitamin content would be high.

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